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AB The bearing steels contain **C** 0.8-1.1, **Si** 0.1-1.5, **Mn** 0.1-1.5, **Cr** 0.2-2.0, **Ni** ≤1.0, **Mo** ≤1.0, **Cu** ≤0.5, W ≤1.0, Nb ≤0.2, V ≤0.5, Al ≤0.05, B ≤0.01 weight%, balance **Fe**, and impurities (Ti ≤0.0030, P ≤0.02, S ≤0.02, N ≤0.0090, O ≤0.0015 weight%) and show average ferrite particle size >1.0 and ≤4.0 μm and average cementite particle size 0.30-0.80 μm. The steels show good cold-workability, machinability, wear resistance, and long rolling contact fatigue life.

PATENT ABSTRACTS OF JAPAN

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(54) STEEL FOR BEARING

(57)Abstract:
PROBLEM TO BE SOLVED: To provide steel for a bearing excellent in cold workability and machinability, and excellent in a rolling fatigue life and in wear resistance.
SOLUTION: This steel for a bearing has a composition containing 0.8 to 1.1% C, 0.1 to 1.5% Si, 0.1 to 1.5% Mn, 0.2 to 2.0% Cr, ≤1.0% Ni, ≤1.0% Mo, ≤0.5% Cu, ≤1.0% W, ≤0.2% Nb, ≤ 0.5% V, ≤0.05% Al and ≤0.01% B, and the balance Fe with impurities, and in which, in the impurities, the content of Ti is controlled to ≤0.0030%, P to ≤0.02%, S to ≤0.02%, N to ≤ 0.0090% and O(oxygen) to ≤0.0015%, and also, the ferrite average grain size is controlled to >1.0 to 4.0 μm, and the cementite average grain size to 0.30 to 0.80 μm.

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CLAIMS

[Claim(s)]
[Claim 1] By mass %, C:0.8 - 1.1%, Si:0.1-1.5%, Mn:0.1-1.5%, Cr: 0.2-2.0%, less than [nickel:1.0%], less than [Mo:1.0%], Cu: Less than [0.5%], W:1.0% or less, less than [Nb:0.2%], V:0.5% or less, The remainder consists of Fe and an impurity including less than [aluminum:0.05%] and B:0.01% or less. For 0.0030% or less and P, 0.02% or less and S are [Ti in an impurity / 0.0090% or less and O (oxygen) of 0.02% or less and N] 0.0015% or less. And the steel materials for bearing 4.0 micrometers or less and whose cementite mean particle diameter ferrite mean particle diameter is 0.30-0.80 micrometers exceeding 1.0 micrometers.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the steel materials for bearing which were especially excellent in the workability and machinability between the colds, such as compression processing, about the steel materials for bearing used for bearing element components, such as a ball, koro, a needle, a shaft, and a ball race.
[0002]
[Description of the Prior Art] Bearing element components, such as a ball, koro, a needle, a shaft, and a ball race Spheroidizing is carried out after carrying out hot working of SUJ2 with means, such as hot rolling and hot forging, conventionally also in SUJ 1-5 which is the high-carbon-chromium bearing steel steel materials standardized by JIS G 4805. Subsequently, cold working, such as cold drawing, cold forging, and cutting, was performed, and annealing at hardening and low temperature was performed after that, and grinding as finish-machining and polish were given further, and it has been manufactured.
[0003] However, in SUJ2, by the manufacture approach currently generally performed, since the carbon more than 0.95 mass % was included, it was easy to generate a crack with cold forging, and since cutting force was high, there was a fault that a tool life was short, at the time of cutting, for example.
[0004] Therefore, the request from the industrial world of wanting to raise the cold-working nature of the steel materials for bearing, to change a production process into cold forging from hot forging, or to extend the tool life in cutting, and to reduce a manufacturing cost sharply is large.
[0005] On the other hand, "the steel for bearing" which contained the specific alloy element in JP,8-53735,A, and specified the rate of a gross area of the amount of carbide after spheroidizing processing to it, for example is indicated. However, since C content is as low as 0.55 - 0.75%, the amount of survival of steel for bearing proposed in this official report of the carbide after hardening / tempering processing will decrease, and the abrasion resistance of bearing element components will fall. Furthermore, in order to change carbide spherically, it is necessary to make the carbide of optimum dose remain at the time of annealing heating but, and in spheroidizing, since C content is low, the manufacture which had to manage the temperature of the steel materials itself in the narrow range, therefore was stabilized in the industrial production scale is difficult for the aforementioned steel for bearing.
[0006] "The steel for bearing" which is excellent in the cold-working nature containing a specific alloy element is indicated by JP,9-302444,A. However, although the "formability in cold forging" as cold-working nature increases in the case of the steel for bearing proposed in this official report, consideration may not be made to improvement in the "machinability" as cold-working nature, therefore the tool life at the time of cutting may be short.
[0007]

[Problem(s) to be Solved by the Invention] This invention was made in view of the above-mentioned present condition, and the purpose is offering the steel materials for bearing excellent in the workability and machinability between the colds, such as compression processing, without spoiling the rolling fatigue life of bearing element components, and abrasion resistance. In addition, for the target of a rolling fatigue life, abrasion resistance, formability in cold forging, and machinability, the life in having each following engine performance by the trial in the below-mentioned example, i.e., a rolling fatigue test, is 1x107. It is that it is above, that it is below the abrasion loss of the steel with which the abrasion loss in an abrasion test is equivalent to SUJ2 steel, that the marginal workability in the compression test between the colds is 75% or more, and that the tool life in a cutting trial is 6.0 minutes or more.

[0008]

[Means for Solving the Problem] The summary of this invention is in the steel materials for bearing shown below. By "mass %, namely, C:0.8 - 1.1%, Si:0.1-1.5%, Mn: 0.1-1.5%, Cr:0.2-2.0%, less than [nickel:1.0%], Mo: Less than [1.0%], less than [Cu:0.5%], W:1.0% or less, less than [Nb:0.2%], Less than [aluminum:0.05%] and B:0.01% or less are included V:0.5% or less. The remainder consists of Fe and an impurity and, for 0.0030% or less and P, 0.02% or less and S are [Ti in an impurity / 0.0090% or less and O (oxygen) of 0.02% or less and N] 0.0015% or less. Ferrite mean particle diameter is and the steel materials for bearing 4.0 micrometers or less and whose cementite mean particle diameter are 0.30-0.80 micrometers exceeding 1.0 micrometers."

[0009] In addition, "ferrite mean particle diameter" is defined as follows. That is, it asks for the area of each ferrite grain first, asks for the diameter of circle which is an area equivalent to the area, and let it be the particle size of the appearance of each ferrite grain. Subsequently, the average of the particle size of the appearance of all the ferrite grains that measured area is made into apparent ferrite mean particle diameter, and what doubled the ferrite mean particle diameter of the above-mentioned appearance 1.12 is defined as ferrite mean particle diameter.

[0010] "Cementite mean particle diameter" is similarly defined as the above-mentioned "ferrite mean particle diameter." That is, it asks for the area of each cementite grain first, asks for the diameter of circle of an area equivalent to the area, and let it be the particle size of the appearance of each cementite grain. Subsequently, the average of the particle size of the appearance of all the cementite grains that measured area is made into apparent cementite mean particle diameter, and what doubled the cementite mean particle diameter of the above-mentioned appearance 1.12 is defined as cementite mean particle diameter.

[0011] In addition, although not restricted especially about the observation approach of a ferrite grain and a cementite grain, it is desirable to observe the cross section of steel materials by 2000 to 5000 times with a scanning electron microscope after polish and corrosion, and to ask for ferrite mean particle diameter and cementite mean particle diameter from the photograph. In addition, each 100 or more grains are contained in the photograph, and, as for the field number, it is desirable that they are four or more places.

[0012] this invention persons were excellent in the workability and machinability between the colds, such as compression processing, and in order to obtain the steel materials for bearing to which a rolling fatigue life long on the bearing element components which performed hardening / tempering processing, and the outstanding abrasion resistance can moreover be made to secure, they repeated an experiment and research variously about the chemical composition and the microstructure of the steel materials for bearing. Consequently, the following knowledge was acquired.

[0013] (a) The steel materials which contained C, Si, Mn, and Cr of the amount of specification, and regulated the content of an impurity element The processing front stirrup between the

colds is a ferrite phase (in a following and book specification) which is a matrix before cutting. not displaying the "phase" in an organization, for example, only saying [a "ferrite"] a "ferrite phase" -- carrying out -- the workability which the workability between the colds improves that it is detailed, and a crack begins to generate, for example, the critical upsetting ratio in a compression test, goes up. Especially, when the mean particle diameter of the ferrite which is a matrix is 4.0 micrometers or less, improvement in cold-working nature becomes remarkable. However, since the increment in the deformation resistance in cold working will become remarkable if the mean particle diameter of a ferrite is set to 1.0 micrometers or less, the life of metal mold will fall at the time of processing.
[0014] (b) Machinability improves that a ferrite is detailed, for example, the tool life in a cutting process by turning long-duration-izes. When the mean particle diameter of the ferrite which is especially a matrix is 4.0 micrometers or less, improvement in machinability is remarkable.
[0015] (c) The direction in the case of including the small angle tilt boundary has [the steel materials which contained C, Si, Mn, and Cr of the amount of specification of the above (a), and regulated the content of an impurity element / the processing front stirrup between the colds] machinability higher than the case where the grain boundary of the ferrite grain before cutting consists of only large inclination grain boundaries. In addition, the bearing difference of the crystal with which the "small angle tilt boundary" adjoined each other by saying the grain boundary whose bearing difference of the crystal with which the "large inclination grain boundary" as used in the field of this invention adjoined each other is 15 degrees or more says what includes the so-called "subgrain boundary" in the grain boundary which is less than 15 degrees.
[0016] (d) In order to raise the cold-working nature and machinability of steel materials of the above (a), the processing front stirrup between the colds should just rationalize the mean particle diameter of the cementite which is main carbide before cutting. Namely, if the mean particle diameter of a cementite is too small, since steel-materials reinforcement will rise, the deformation resistance in cold working will increase and the life of metal mold will fall at the time of processing. Furthermore, the cutting force in cutting increases and machinability also falls. On the other hand, if the mean particle diameter of a cementite is too large, since a cementite serves as a crack generating origin at the time of cold working, cold-working nature will fall, for example, the critical upsetting ratio in a compression test will fall. This invention is completed based on the above-mentioned knowledge.
[0017]
[Embodiment of the Invention] Hereafter, this invention is explained in detail. In addition, "% of the content" of a chemical entity means "mass %."
(A) C:0.8 - 1.1% of chemical composition C has the operation which rationalizes the amount of cementite survival under steel-materials organization after hardening annealing, and raises abrasion resistance. However, at less than 0.8%, the content is deficient in the addition effectiveness, and cannot secure desired abrasion resistance easily. On the other hand, since the above-mentioned big and rough carbide will remain even if it becomes easy to generate very big and rough carbide and performs homogenization heat treatment at the time of the coagulation of steel if the content of C exceeds 1.1%, a target rolling fatigue life is not acquired but cold-working nature also falls further. Therefore, the content of C was made into 0.8 - 1.1%. In addition, as for the content of C, considering as 0.9 - 1.0% is desirable.
[0018] Si: 0.1 - 1.5%Si has deacidification while raising a rolling fatigue life. In order to demonstrate such effectiveness, it is required to make 0.1% or more of Si contain. On the other hand, if the content of Si exceeds 1.5%, cold-working nature will deteriorate, for example, in case it is cold forging, it becomes easy to generate a crack. Therefore, the content of Si was made into 0.1 - 1.5%. In addition, as for the content of Si, considering as 0.2 - 0.8% is desirable.

[0019] Mn: 0.1 - 1.5%Mn has the operation which prevents the hot shortness by S while raising the hardenability of steel. In order to demonstrate such effectiveness, it is necessary to make Mn contain 0.1% or more. On the other hand, if the content of Mn exceeds 1.5%, cold-working nature will deteriorate, for example, in case it is cold forging, it becomes easy to generate a crack. Therefore, the content of Mn was made into 0.1 - 1.5%. In addition, as for the content of Mn, considering as 0.3 - 1.2% is desirable.
[0020] Cr: 0.2-2.0%Cr is an element which raises the hardenability of steel. Furthermore, since Cr condenses in a cementite and stabilizes a cementite in an austenite, the range can be made large whenever [for hardening / spheroidizing or stoving temperature], and manufacture of steel materials becomes easy. In order to demonstrate such effectiveness, it is necessary to make Cr contain 0.2% or more. However, since the above-mentioned big and rough carbide will remain even if it becomes easy to generate very big and rough carbide and performs homogenization heat treatment at the time of the coagulation of steel if the content of Cr exceeds 2.0%, a target rolling fatigue life is not acquired. Therefore, the content of Cr was made into 0.2 - 2.0%. In addition, as for the content of Cr, considering as 0.4 - 1.2% is desirable.
[0021] nickel: It is not necessary to add nickel 1.0% or less. If it adds, it has the operation which raises hardenability and raises a rolling fatigue life. In order to acquire this effectiveness certainly, as for the content of nickel, considering as 0.1% or more is desirable. However, if the content exceeds 1.0%, even if it hardens, the amount of the austenite (the so-called "retained austenite") which remains with un-metamorphosing will increase, and a rolling fatigue life will fall on the contrary. Therefore, the content of nickel was made into 1.0% or less. In addition, as for the upper limit of nickel content, considering as 0.8% is desirable.
[0022] Mo: It is not necessary to add Mo 1.0% or less. If it adds, it has the operation which raises hardenability and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, as for Mo, it is desirable to consider as 0.1% or more of content. However, if the content exceeds 1.0%, cold-working nature deteriorates, for example, in case it is cold forging, it will become easy to generate a crack. Therefore, the content of Mo was made into 1.0% or less. In addition, as for the upper limit of Mo content, considering as 0.6% is desirable.
[0023] Cu: It is not necessary to add less than [0.5%] Cu. If it adds, it has the operation which deposits minutely and raises a rolling fatigue life in steel. In order to acquire this effectiveness certainly, as for Cu, it is desirable to consider as 0.05% or more of content. However, if the content exceeds 0.5%, heat slowing nature may fall and a crack may occur in the case of processing between heat. Therefore, the content of Cu was made into 0.5% or less. In addition, as for the upper limit of Cu content, considering as 0.3% is desirable.
[0024] It is not necessary to add W:1.0%or less W. If it adds, it combines with C, detailed WC is formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, it is desirable to make the content of W into 0.05% or more. However, if the content exceeds 1.0%, since big and rough WC will be generated at the time of coagulation, a rolling fatigue life falls on the contrary. Therefore, the content of W was made into 1.0% or less. In addition, as for the upper limit of W content, considering as 0.3% is desirable.
[0025] Nb: It is not necessary to add less than [0.2%] Nb. If it adds, it combines with C, detailed NbC is formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to acquire this effectiveness certainly, as for Nb, it is desirable to consider as 0.03% or more of content. However, if the content exceeds 0.2%, since big and rough NbC will be generated at the time of coagulation, a rolling fatigue life falls on the contrary. Therefore, the content of Nb was made into 0.2% or less. In addition, as for the upper limit of Nb content, considering as 0.1% is desirable.
[0026] It is not necessary to add V:0.5%or less V. If it adds, it combines with C, detailed VC is

formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, it is desirable to make the content of V into 0.05% or more. However, if the content exceeds 0.5%, since big and rough VC will be generated at the time of coagulation, a rolling fatigue life will fall on the contrary. Therefore, the content of V was made into 0.5% or less. In addition, as for the upper limit of V content, considering as 0.2% is desirable.
[0027] aluminum: It is not necessary to add aluminum 0.05% or less. It has deacidification, if it adds. In order to acquire this effectiveness certainly, as for aluminum, it is desirable to consider as 0.003% or more of content. However, if the content exceeds 0.05%, it will become easy to generate big and rough nonmetal system inclusion, and a target rolling fatigue life will not be acquired. Therefore, the content of aluminum was made into 0.05% or less. In addition, as for the upper limit of aluminum content, considering as 0.03% is desirable.
[0028] It is not necessary to add B:0.01%or less B. Abrasion resistance is raised, while dissolving in a cementite, stabilizing a cementite and enabling compaction of spheroidizing time amount, if it adds. In order to acquire such effectiveness certainly, as for B, it is desirable to consider as 0.0005% or more of content. However, if the content exceeds 0.01%, it will become easy to generate big and rough BN, and a target rolling fatigue life will not be acquired. Therefore, the content of B was made into 0.01% or less. In addition, as for the upper limit of B content, considering as 0.005% is desirable.
[0029] In this invention, the content of Ti, P, S, N, and O (oxygen) as an impurity element is restricted as follows.
[0030] Ti: 0.0030%or less Ti will combine with N, will form TiN, and will reduce a rolling fatigue life. If especially the content exceeds 0.0030%, the fall of a rolling fatigue life will become remarkable. Therefore, the content of Ti was made into 0.0030% or less.
[0031] Since it is easy to segregate P:0.02%or less P to a grain boundary, it will reduce a rolling fatigue life. When especially the content exceeds 0.02%, the fall of a rolling fatigue life is remarkable. Therefore, the content of P was made into 0.02% or less.
[0032] S:0.02%or less S combines with Mn, forms MnS, and may reduce a rolling fatigue life. If especially the content exceeds 0.02%, it will become easy to generate big and rough MnS, and the fall of a rolling fatigue life will become remarkable. Therefore, the content of S was made into 0.02% or less. However, since MnS is effective in improvement in machinability, it is desirable that S as an impurity element is included 0.005% or more from the field of machinability.
[0033] N:0.0090%or less N will combine with Ti or B, will form TiN and BN, and will reduce a rolling fatigue life. If especially the content exceeds 0.0090%, the fall of a rolling fatigue life will become remarkable. Therefore, the content of N was made into 0.0090% or less. In addition, in order to make a rolling fatigue life big, it is desirable to make the content of N into 0.0060% or less.
[0034] O (oxygen):0.0015%or less O will form oxide system inclusion, and will reduce a rolling fatigue life. When especially the content exceeds 0.0015%, the fall of a rolling fatigue life is remarkable. Therefore, the content of O was made into 0.0015% or less.
[0035] This invention does not need to add special limitation about other chemical entities other than the above in the target steel materials for bearing. Grant of the final product which consists of bearing element components and them, i.e., the property required of bearing, must be possible, and it must be the component range where the outstanding cold-working nature and machinability are obtained.
[0036] As an element except said, less than [Pb:0.30%], less than [rare-earth-elements:0.10%], less than [calcium:0.01%], and less than [Mg:0.01%] are contained, and, specifically, the remainder should just consist of Fe and an unescapable impurity.
[0037] In addition, when carrying out additional content of the above-mentioned element for the

purpose of the improvement in a property of the bearing which is steel materials, bearing element components, and a final product etc., it is desirable respectively to consider as a content (Pb:0.02-0.30%, rare-earth-elements:0.002-0.10%, calcium:0.0005-0.01%, and Mg:0.0005-0.01%).
(B) The workability which cold-working nature of steel materials of the chemical composition stated by the ferrite mean-particle-diameter above-mentioned (A) term improves that the processing front stirrup between the colds has the detailed ferrite grain which is a matrix before cutting, and a crack begins to generate, for example, the critical upsetting ratio in a compression test, goes up. Especially, when the mean particle diameter of a ferrite is 4.0 micrometers or less, improvement in cold-working nature becomes remarkable. On the other hand, from the point of raising cold-working nature, as ferrite mean particle diameter is small, it is better, but if the mean particle diameter of a ferrite is set to 1.0 micrometers or less, the increment in the deformation resistance between the colds will become remarkable, and the life of metal mold will fall remarkably at the time of processing. Therefore, the mean particle diameter of a ferrite was specified as 4.0 micrometers or less exceeding 1.0 micrometers. In addition, in order to control the fall of the mold life at the time of cold working, as for the mean particle diameter of a ferrite, it is desirable to make it 1.5 micrometers or more.
[0038] "Ferrite mean particle diameter" is defined as having already stated as follows. That is, it asks for the area of each ferrite grain first, asks for the diameter of circle which is an area equivalent to the area, and let it be the particle size of the appearance of each ferrite grain. Subsequently, the average of the particle size of the appearance of all the ferrite grains that measured area is made into apparent ferrite mean particle diameter, and what doubled the ferrite mean particle diameter of the above-mentioned appearance 1.12 is defined as ferrite mean particle diameter.
[0039] In addition, the direction in the case of including the small angle tilt boundary has machinability higher than the case where the grain boundary of the ferrite grain before cutting consists of only large inclination grain boundaries, and when especially the percentage of a small angle tilt boundary is 30% or more, machinability of the processing front stirrup between the colds improves. For this reason, as for the processing front stirrup between the colds, it is [the grain boundary of the ferrite grain before cutting] desirable for those 30% or more to be a small angle tilt boundary. As already stated, the grain boundary whose bearing difference of the crystal with which the "large inclination grain boundary" in this invention adjoined each other is 15 degrees or more is said, and a "small angle tilt boundary" points out that in which the bearing difference of the adjacent crystal includes the so-called "subgrain boundary" in the grain boundary which is less than 15 degrees.
(C) If the mean particle diameter of a cementite mean-particle-diameter cementite is too small, since steel-materials reinforcement will rise, the deformation resistance in cold working will increase and the mold life at the time of processing will fall. Furthermore, the cutting force in cutting increases and machinability also falls. Such a phenomenon becomes remarkable when the mean particle diameter of a cementite is less than 0.30 micrometers. On the other hand, if the mean particle diameter of a cementite is too large, since a cementite serves as a crack generating origin at the time of cold working, cold-working nature will fall, for example, the critical upsetting ratio in a compression test will fall. This phenomenon will become remarkable if the mean particle diameter of a cementite exceeds 0.80 micrometers. Therefore, cementite mean particle diameter was specified as 0.30-0.80 micrometers. "Cementite mean particle diameter" is defined as having already stated as follows. That is, it asks for the area of each cementite grain first, asks for the diameter of circle of an area equivalent to the area, and let it be the particle size of the appearance of each cementite grain. Subsequently, the average of the particle size of the appearance of all the cementite grains that measured area is made into apparent cementite mean particle diameter, and what doubled the cementite mean particle

diameter of the above-mentioned appearance 1.12 is defined as cementite mean particle diameter.
[0040] The steel materials for bearing which have the chemical composition indicated in the aforementioned (A) term For example, the round bar with a diameter of 30mm hot-rolled and obtained by the usual approach (A1 Point +15) - (A1 point +40), after heating in the temperature region of ** for 2 to 4 hours After cooling to the temperature of ** at least (A1 point -80) with the cooling rate of 10-15 degrees C/o'clock, it cools radiationally among atmospheric air. After carrying out cold drawing at 20 - 40% of reduction of area further after that - (A1 point -20) (A1 point -60), ferrite mean particle diameter and cementite mean particle diameter can be adjusted to the value stated by the (B) term and the (C) term by heating by ** for 0.5 to 2 hours. Subsequently, the steel materials are rough-fabricated by the desired configuration by cold forging or cutting, and after receiving hardening and annealing after that, machining grinding, polish, etc. further and making a desired precise element part shape, they are assembled by the bearing as a final product which is a precision machinery component.
[0041] In addition, what combined the cold drawing of the spheroidizing conditions of "I" in the below-mentioned example and 32% of reduction of area and the heat treatment conditions of "Y" agrees on the adjustment conditions of the above-mentioned ferrite mean particle diameter and cementite mean particle diameter.
[0042] In addition, said A1 A point points out the value calculated from the following formula considering the symbol of element in a formula as a content in mass % of the element.
[0043] A1 Point =723-10.7Mn-16.9nickel+29.1Si+16.9Cr+6.4 (W+Mo).
[0044]
[Example] Steel A-J which has the chemical composition shown in Table 1 was ingoted using 300kg vacuum furnace by the usual approach. In addition, the chemical composition of the steel A in Table 1 is equivalent to SUJ2 of JIS.
[0045]
[Table 1]

表　1

鋼	化学組成（質量%）　残部：Feおよび不純物																
	C	Si	Mn	Cr	Ni	Mo	Cu	W	Nb	V	Al	B	Ti	S	P	N	O
A	1.00	0.25	0.32	1.41	-	-	-	-	-	-	0.021	-	0.0012	0.008	0.005	0.0048	0.0008
B	*0.74	0.23	0.33	1.43	-	-	-	-	-	-	0.023	-	0.0011	0.007	0.006	0.0045	0.0007
C	0.84	0.24	0.34	1.42	-	-	-	-	-	-	0.020	0.0048	0.0012	0.008	0.006	0.0046	0.0008
D	*1.14	0.23	0.35	1.40	-	-	-	-	-	-	0.018	-	0.0010	0.009	0.005	0.0043	0.0007
E	0.89	0.52	0.80	0.75	0.51	-	0.24	-	-	-	0.028	-	0.0021	0.008	0.007	0.0045	0.0010
F	0.94	0.40	1.05	0.41	-	0.20	-	0.23	-	-	0.026	-	0.0012	0.006	0.005	0.0058	0.0009
G	0.85	0.45	0.52	1.02	-	-	-	-	0.012	0.022	0.001	-	0.0008	0.007	0.004	0.0041	0.0011
H	0.90	0.25	0.72	0.84	-	-	-	-	-	-	0.023	-	*0.0033	0.008	0.006	0.0047	0.0006
I	0.91	0.24	0.71	0.83	-	-	-	-	-	-	0.024	-	0.0012	0.006	0.006	*0.0095	0.0008
J	0.90	0.24	0.74	0.81	-	-	-	-	-	-	0.021	-	0.0009	0.008	0.005	0.0043	*0.0017

*印は本発明で規定する範囲から外れていることを表す 。
Ni,Mo,Cu,Wの欄の「-」は0.01%未満、Nb,Vの欄の「-」は0.001%未満、Bの欄の「-」は0.0001%未満を表す。

Subsequently, after carrying out soaking of the steel materials of such steel at 1230 degrees C for 8 hours, hot forging was carried out by the usual approach in the 1150-950-degree C temperature region, and it considered as the round bar whose diameter is 50mm.
[0046] Then, spheroidizing was performed on condition that following I, RO, or Ha.
[0047] I: Cool to 660 degrees C in o'clock in 60 degrees C /, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 1 hour.
[0048] RO: Cool to 660 degrees C in o'clock in 10 degrees C /, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 4 hours.

[0049] Ha: Cool to 660 degrees C in o'clock in 5 degrees C /after cooling to 680 degrees C in o'clock in 5 degrees C /and reheating at 770 degrees C after that for 6 hours, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 6 hours.
[0050] Thus, after carrying out the grinding process of the front face of the obtained round bar and making it the round bar with a diameter of 45mm, cold drawing was carried out by the usual approach, and it was processed into the round bar (the diameter of 42mm (the reduction of area from the diameter of 45mm: 13%), 37mm (the reduction of area from the diameter of 45mm: 32%), and 29mm (the reduction of area from the diameter of 45mm: 58%)). Subsequently, it heat-treated on condition that either Following X, or Y and Z about the round bar which carried out [above-mentioned] cold drawing, respectively.
[0051] Radiationnal cooling among atmospheric air after heating at X:600 degrees C for 1 hour.
[0052] Radiationnal cooling among atmospheric air after heating at Y:700 degrees C for 1 hour.
[0053] Radiationnal cooling among atmospheric air after heating at Z:700 degrees C for 8 hours.
[0054] After carrying out cold drawing to 42-29mm for the round bar which carried out the grinding process to 45mm after spheroidizing, and a diameter, ferrite mean particle diameter and cementite mean particle diameter were measured about the round bar which heat-treated on condition that either of said X-Z.
[0055] That is, after carrying out mirror polishing of the cross section (that is, cutting plane right-angled in the die-length direction) of each round bar, it corroded in picral. Subsequently, it observed five visual fields each by one 5000 times the scale factor of this using the scanning electron microscope, and by the image analysis by the usual approach, it asked for the area of each ferrite grain and each cementite grain, and the diameter of circle of an area equivalent to it was calculated, and the average of a diameter of circle was respectively calculated about the ferrite grain and the cementite grain. What doubled the average of this diameter of circle 1.12, respectively was made into ferrite mean particle diameter and cementite mean particle diameter. Moreover, about the round bar which uses steel A as material steel, mirror polishing and after carrying out electrolytic polishing, bearing of a ferrite grain was measured for the cross section of each round bar by the electron ray backscattering pattern method (EBSP), and it asked for the rate of a small angle tilt boundary.
[0056] The cold-working trial was performed as follows. That is, after cutting down the test piece with a die length of 21mm for the diameter of 14mm from the round bar produced with said monograph affair, compressing the test piece, where the both-ends side of a test piece is restrained, and compressing 15% of the original test piece die length (21mm) in the 0.5/second of rate of strains, it repeated carrying out unloading 4 times. Then, after the original test piece die length's having compressed by a unit of 2% further and carrying out unloading, the test piece was observed with the naked eye, and the existence of a crack was checked. It continued until the crack generated this in the test piece. In addition, the above-mentioned trial was performed using ten test pieces each, and workability which a crack began to generate in five or more test pieces among ten test pieces was made into marginal workability. In addition, it asked for marginal workability from the following formula.
[0057] Marginal workability (%) =100 (21-h) / 21. Here, h points out the height in mm unit of the test piece which a crack began to generate to five or more test pieces.
[0058] The target of cold-working nature (compressibility between the colds) was carried out compared with the marginal workability (70%) in the test number 3 using the steel A equivalent to SUJ2 of JIS to the thing high 5% or more, i.e., have 75% or more of marginal workability.
[0059] The cutting trial was also performed. That is, acid washing of the round bar produced with said monograph affair was carried out by the usual approach, the cutting process by

turning was performed using what removed the scale, time amount until it becomes impossible for a tool to cut by wear or the chip was measured, and the tool life was searched for. The cutting process by turning was performed on condition that a part for /and the amount of slitting of 0.5mm of peripheral speed of 50m, and feed-per-revolution 0.25 mm/rev., and used the triangular chip of SKH4 of JIS for the tool. In addition, lubricant was not used.
[0060] It was presupposed to the target of machinability that it has a ********; i.e., the tool life for 6.0 minutes or more, 50% or more compared with the tool life (4.0 minutes) in the test number 3 using the steel A equivalent to SUJ2 of JIS.
[0061] The test piece with a die length of 22mm was cut down for the diameter of 12mm from the round bar produced with said monograph affair, annealing of 1 hour was given at oil-quenching of maintenance, and 160 degrees C by 820 degrees C for 30 minutes, and the rolling fatigue test was performed.
[0062] That is, using the cylindrical rolling fatigue tester, #60 spindle oil was used for the lubricating oil, and Hertz best osculation stress performed the rolling fatigue test on the load conditions of 4900MPa(s) (500kgf/mm2) and rotational-speed 46000rpm. It made the test piece into ten pieces at a time about said monograph affair, and the total rotational frequency when causing surface exfoliation first in ten test pieces was made into the "rolling fatigue life." In addition, the target of a rolling fatigue life is 1x107. It considered as the above.
[0063] Furthermore, the test piece with a die length of 10mm was cut down for the diameter of 28mm from the round bar produced with said monograph affair, annealing of 1 hour was given at oil-quenching of maintenance, and 160 degrees C by 820 degrees C for 30 minutes, and the abrasion test was performed. That is, using an Ogoe style abrasion tester, SCM420 which adjusted hardness to 87 by HRB was made into partner material, and was performed on condition that the friction velocity of 1m/second, the friction distance of 400m, 59 Ns (6kgf) of breaking loads, and non-lubrication. It made the test piece into five pieces at a time about each steel, and the average of the abrasion loss of five test pieces was made into abrasion loss. In addition, the wear-resistant target was made into 1.0 or less abrasion loss at the time of setting abrasion loss in the test number 3 using the steel A equivalent to SUJ2 of JIS to 1.0.
[0064] The conditions of spheroidizing, the reduction of area at the time of wire drawing, ferrite mean particle diameter, cementite mean particle diameter, the marginal workability [in / comparatively / the compression test between the colds] of the small angle tilt boundary in a ferrite grain boundary, the tool life in a cutting trial, the rolling fatigue life in a rolling fatigue test, and the abrasion loss in an abrasion test are collectively shown in Table 2 and Table 3.
[0065]
[Table 2]

表 2

試験番号	鋼	球状化焼鈍の条件	冷間伸線減面率(%)	冷間伸線後の熱処理	フェライト平均粒径(μm)	セメンタイト平均粒径(μm)	小傾角粒界の割合(%)	限界加工度(%)	工具寿命(分)	転動疲労寿命(回)	摩耗量
1		イ	0	なし	*12.8	*0.24	12	** 68	**1.5	3.8×10^7	1.0
2		イ	32	Y	* 0.8	*0.27	49	76	**4.5	3.9×10^7	1.0
3		ロ	0	なし	*14.3	0.48	10	** 70	**4.0	4.3×10^7	1.0
4		ロ	13	Y	*13.4	0.50	15	** 68	**4.5	4.3×10^7	1.0
5	A	ロ	32	X	* 8.6	0.49	31	** 70	**3.0	4.3×10^7	1.0
6		ロ	32	Y	1.2	0.51	63	82	9.5	4.5×10^7	1.0
7		ロ	32	Z	1.8	0.58	37	78	10.0	4.2×10^7	1.0
8		ロ	58	Y	1.1	0.51	50	80	11.5	4.3×10^7	1.0
9		ハ	0	なし	*20.1	*0.83	6	** 68	6.0	4.0×10^7	1.0
10		ハ	32	Y	1.7	*0.85	44	** 70	14.5	4.2×10^7	1.0
11		ロ	32	X	* 6.5	0.42	−	** 72	6.5	2.5×10^7	**1.6
12	*B	ロ	32	Y	1.6	0.43	−	84	12.0	2.7×10^7	**1.6
13		ロ	32	Z	* 2.9	0.47	−	80	8.5	3.0×10^7	**1.6
14		ロ	0	なし	*15.2	0.44	−	** 72	**5.5	3.9×10^7	0.9
15		ロ	13	Y	* 7.7	0.45	−	** 70	**4.5	4.3×10^7	0.9
16	C	ロ	32	X	*14.5	0.44	−	** 68	**3.5	4.3×10^7	0.9
17		ロ	32	Y	1.5	0.46	−	80	13.0	4.3×10^7	0.9
18		ロ	32	Z	* 4.3	0.50	−	** 74	7.0	4.5×10^7	0.9
19		ロ	58	Y	1.2	0.46	−	82	13.5	4.2×10^7	0.9
20		ロ	32	X	* 9.4	0.62	−	** 66	**1.5	**6.3×10^6	0.7
21	*D	ロ	32	Y	* 4.8	0.63	−	** 68	**1.0	**5.8×10^6	0.7
22		ロ	32	Z	1.6	0.66	−	76	7.0	**6.0×10^6	0.7
23		ロ	0	なし	*12.0	0.45	−	** 72	**5.5	6.2×10^7	1.0
24	E	ロ	13	Y	*10.8	0.47	−	** 70	**4.5	6.4×10^7	1.0
25		ロ	32	X	*11.5	0.46	−	** 70	7.0	6.3×10^7	1.0

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**印は、目標に達していないことを示す。
小傾角粒界の割合における「−」は測定していないことを示す。
摩耗量は試験番号3の摩耗量を1．0とした場合の相対的な値を示す。

[Table 3]

表 3

試験番号	鋼	球状化焼鈍の条件	冷間伸線減面率 (%)	冷間伸線後の熱処理	フェライト平均粒径 (μm)	セメンタイト平均粒径 (μm)	小傾角粒界の割合 (%)	限界加工度 (%)	工具寿命 (分)	転動疲労寿命 (回)	摩耗量
26		ロ	32	Y	1.6	0.47	—	82	12.0	6.8×10^7	1.0
27		ロ	32	Z	2.8	0.51	—	76	9.5	5.9×10^7	1.0
28		ロ	58	Y	1.5	0.47	—	84	13.0	6.3×10^7	1.0
29		ロ	0	なし	*9.7	0.51	—	**68	**7.6	7.3×10^7	0.5
30	F	ロ	13	Y	*9.3	0.52	—	**70	**3.5	6.9×10^7	0.5
31		ロ	32	X	*9.6	0.51	—	**66	**4.0	7.0×10^7	0.5
32		ロ	32	Y	*5.1	0.52	—	**72	**5.5	7.2×10^7	0.5
33		ロ	32	Z	1.6	0.55	—	78	8.0	6.5×10^7	0.5
34		ロ	58	Y	1.2	0.52	—	80	9.5	7.1×10^7	0.5
35		ロ	0	なし	*7.9	0.45	—	**64	**2.0	8.2×10^7	0.7
36		ロ	13	Y	*7.2	0.46	—	**66	**1.5	7.5×10^7	0.7
37	G	ロ	32	X	*7.0	0.45	—	**68	**3.0	7.7×10^7	0.7
38		ロ	32	Y	3.4	0.46	—	76	6.5	8.0×10^7	0.7
39		ロ	32	Z	1.3	0.50	—	76	8.5	7.9×10^7	0.7
40		ロ	58	Y	1.2	0.47	—	78	9.0	7.3×10^7	0.7
41		ロ	32	X	*13.5	0.48	—	**70	**5.5	**5.2×10^6	0.9
42	*H	ロ	32	Y	1.6	0.49	—	78	11.0	**5.8×10^6	0.9
43		ロ	32	Z	*3.1	0.54	—	**74	8.5	**5.6×10^6	0.9
44		ロ	32	X	*12.9	0.48	—	**70	**4.5	**8.0×10^6	0.9
45	*I	ロ	32	Y	1.5	0.50	—	80	9.0	**8.3×10^6	0.9
46		ロ	32	Z	*4.3	0.55	—	**74	6.5	**7.6×10^6	0.9
47		ロ	32	X	*13.2	0.49	—	**68	**5.0	**2.7×10^6	0.9
48	*J	ロ	32	Y	1.5	0.50	—	78	12.5	**3.0×10^6	0.9
49		ロ	32	Z	3.3	0.56	—	76	9.0	**2.3×10^6	0.9

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小傾角粒界の割合における「—」は測定していないことを示す。
摩耗量は試験番号3の摩耗量を1．0とした場合の相対的な値を示す。

In the case of the test numbers 6-8 which fill the provision of this invention from Table 2 and Table 3, 17, 19, 26-28, 33 and 34, and 38-40, it is 75% or more of marginal workability, a tool life for 6.0 minutes or more, and 1x107. The above rolling fatigue life is acquired and the abrasion resistance on the basis of the abrasion loss of a test number 3 is also good. On the other hand, even if there are little marginal workability, tool life, rolling fatigue life, and abrasion resistance in the case of the test number from which it separated from the provision of this invention, either has not reached a target.
[0066] Even if it is the case where Steel A and C and E-G which have chemical composition within the limits of the content specified by this invention are used as material steel, since [of ferrite mean particle diameter and cementite mean particle diameter] either separates from the provision of this invention at least, as for test numbers 1-5, 9, 10, 14-16, 18, 23-25, 29-32, and 35-37, marginal workability, one of tool lives, or both sides has not reached a target.
[0067] Namely, since cementite mean particle diameter is less than 0.30 micrometers while ferrite mean particle diameter exceeds 4.0 micrometers, a test number 1 has marginal workability as small as 68%, and its tool life is also as short as 1.5 minutes.
[0068] Since cementite mean particle diameter is less than 0.30 micrometers, a test number 2 has a tool life as short as 4.5 minutes.
[0069] In order that ferrite mean particle diameter may exceed 4.0 micrometers, test numbers 3-5, 23, 24, 29-32, and 35-37 have low marginal workability, and its a tool life is also short.

[0070] A test number 9 has marginal workability as small as 68%, in order that ferrite mean particle diameter may exceed [4.0 micrometers] 0.80 micrometers also for cementite mean particle diameter with an upper time.
[0071] In order that, as for a test number 10, cementite mean particle diameter may exceed 0.80 micrometers, marginal workability has not reached desired value at 70%. In order that ferrite mean particle diameter may exceed 4.0 micrometers, test numbers 14-16, and 18 and 25 have low marginal workability. On the other hand, since C content of the steel B which is material steel is less than 0.8%, there is much abrasion loss and test numbers 11-13 are inferior in abrasion resistance. Among these, as for the test number 11, marginal workability has not reached desired value, either.
[0072] Test numbers 20-22 have a short rolling fatigue life, in order that C content of the steel D which is material steel may exceed 1.1%. Among these, as for test numbers 20 and 21, marginal workability has not reached desired value, either.
[0073] In order that the content of Ti, N, and O (oxygen) of steel H-J which is material steel may exceed 0.0030%, 0.0090%, and 0.0015%, respectively, test numbers 41-43, 44-46, and 47-49 have a short rolling fatigue life. Among these, as for test numbers 41, 43, 44, 46, and 47, marginal workability has not reached desired value, either. Furthermore, in the case of test numbers 41, 44, and 47, a tool life is also short.
[0074]
[Effect of the Invention] Since it excels in the workability and machinability between the colds and a rolling fatigue life and abrasion resistance moreover are not spoiled, the steel materials for bearing of this invention can be used for bearing element components, such as a ball, koro, a needle, a shaft, and a ball race.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the steel materials for bearing which were especially excellent in the workability and machinability between the colds, such as compression processing, about the steel materials for bearing used for bearing element components, such as a ball, koro, a needle, a shaft, and a ball race.

[Translation done.]

PRIOR ART

[Description of the Prior Art] Bearing element components, such as a ball, koro, a needle, a shaft, and a ball race Spheroidizing is carried out after carrying out hot working of SUJ2 with means, such as hot rolling and hot forging, conventionally also in SUJ 1-5 which is the high-carbon-chromium bearing steel steel materials standardized by JIS G 4805. Subsequently, cold working, such as cold drawing, cold forging, and cutting, was performed, and annealing at hardening and low temperature was performed after that, and grinding as finish-machining and polish were given further, and it has been manufactured.
[0003] However, in SUJ2, by the manufacture approach currently generally performed, since the carbon more than 0.95 mass % was included, it was easy to generate a crack with cold forging, and since cutting force was high, there was a fault that a tool life was short, at the time of cutting, for example.
[0004] Therefore, the request from the industrial world of wanting to raise the cold-working nature of the steel materials for bearing, to change a production process into cold forging from hot forging, or to extend the tool life in cutting, and to reduce a manufacturing cost sharply is large.
[0005] On the other hand, "the steel for bearing" which contained the specific alloy element in JP,8-53735,A, and specified the rate of a gross area of the amount of carbide after spheroidizing processing to it, for example is indicated. However, since C content is as low as 0.55 - 0.75%, the amount of survival of steel for bearing proposed in this official report of the carbide after hardening / tempering processing will decrease, and the abrasion resistance of bearing element components will fall. Furthermore, in order to change carbide spherically, it is necessary to make the carbide of optimum dose remain at the time of annealing heating but, and in spheroidizing, since C content is low, the manufacture which had to manage the temperature of the steel materials itself in the narrow range, therefore was stabilized in the industrial production scale is difficult for the aforementioned steel for bearing.
[0006] "The steel for bearing" which is excellent in the cold-working nature containing a specific alloy element is indicated by JP,9-302444,A. However, although the "formability in cold forging" as cold-working nature increases in the case of the steel for bearing proposed in this official report, consideration may not be made to improvement in the "machinability" as cold-working nature, therefore the tool life at the time of cutting may be short.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] Since it excels in the workability and machinability between the colds and a rolling fatigue life and abrasion resistance moreover are not spoiled, the steel materials for bearing of this invention can be used for bearing element components, such as a ball, koro, a needle, a shaft, and a ball race.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] This invention was made in view of the above-mentioned present condition, and the purpose is offering the steel materials for bearing excellent in the workability and machinability between the colds, such as compression processing, without spoiling the rolling fatigue life of bearing element components, and abrasion resistance. In addition, for the target of a rolling fatigue life, abrasion resistance, formability in cold forging, and machinability, the life in having each following engine performance by the trial in the below-mentioned example, i.e., a rolling fatigue test, is 1x107. It is that it is above, that it is below the abrasion loss of the steel with which the abrasion loss in an abrasion test is equivalent to SUJ2 steel, that the marginal workability in the compression test between the colds is 75% or more, and that the tool life in a cutting trial is 6.0 minutes or more.

[Translation done.]

MEANS

[Means for Solving the Problem] The summary of this invention is in the steel materials for bearing shown below. By "mass %, namely, C:0.8 - 1.1%, Si:0.1-1.5%, Mn: 0.1-1.5%, Cr:0.2-2.0%, less than [nickel:1.0%], Mo: Less than [1.0%], less than [Cu:0.5%], W:1.0% or less, less than [Nb:0.2%], Less than [aluminum:0.05%] and B:0.01% or less are included V:0.5% or less. The remainder consists of Fe and an impurity and, for 0.0030% or less and P, 0.02% or less and S are [Ti in an impurity / 0.0090% or less and O (oxygen) of 0.02% or less and N] 0.0015% or less. Ferrite mean particle diameter is and the steel materials for bearing 4.0 micrometers or less and whose cementite mean particle diameter are 0.30-0.80 micrometers exceeding 1.0 micrometers."
[0009] In addition, "ferrite mean particle diameter" is defined as follows. That is, it asks for the area of each ferrite grain first, asks for the diameter of circle which is an area equivalent to the area, and let it be the particle size of the appearance of each ferrite grain. Subsequently, the average of the particle size of the appearance of all the ferrite grains that measured area is made into apparent ferrite mean particle diameter, and what doubled the ferrite mean particle diameter of the above-mentioned appearance 1.12 is defined as ferrite mean particle diameter.

[0010] "Cementite mean particle diameter" is similarly defined as the above-mentioned "ferrite mean particle diameter." That is, it asks for the area of each cementite grain first, asks for the diameter of circle of an area equivalent to the area, and let it be the particle size of the appearance of each cementite grain. Subsequently, the average of the particle size of the appearance of all the cementite grains that measured area is made into apparent cementite mean particle diameter, and what doubled the cementite mean particle diameter of the above-mentioned appearance 1.12 is defined as cementite mean particle diameter.
[0011] In addition, although not restricted especially about the observation approach of a ferrite grain and a cementite grain, it is desirable to observe the cross section of steel materials by 2000 to 5000 times with a scanning electron microscope after polish and corrosion, and to ask for ferrite mean particle diameter and cementite mean particle diameter from the photograph. In addition, each 100 or more grains are contained in the photograph, and, as for the field number, it is desirable that they are four or more places.
[0012] this invention persons were excellent in the workability and machinability between the colds, such as compression processing, and in order to obtain the steel materials for bearing to which a rolling fatigue life long on the bearing element components which performed hardening / tempering processing, and the outstanding abrasion resistance can moreover be made to secure, they repeated an experiment and research variously about the chemical composition and the microstructure of the steel materials for bearing. Consequently, the following knowledge was acquired.
[0013] (a) The steel materials which contained C, Si, Mn, and Cr of the amount of specification, and regulated the content of an impurity element The processing front stirrup between the

colds is a ferrite phase (in a following and book specification) which is a matrix before cutting. not displaying the "phase" in an organization, for example, only saying [a "ferrite"] a "ferrite phase" -- carrying out -- the workability which the workability between the colds improves that it is detailed, and a crack begins to generate, for example, the critical upsetting ratio in a compression test, goes up. Especially, when the mean particle diameter of the ferrite which is a matrix is 4.0 micrometers or less, improvement in cold-working nature becomes remarkable. However, since the increment in the deformation resistance in cold working will become remarkable if the mean particle diameter of a ferrite is set to 1.0 micrometers or less, the life of metal mold will fall at the time of processing.

[0014] (b) Machinability improves that a ferrite is detailed, for example, the tool life in a cutting process by turning long-duration-izes. When the mean particle diameter of the ferrite which is especially a matrix is 4.0 micrometers or less, improvement in machinability is remarkable.

[0015] (c) The direction in the case of including the small angle tilt boundary has [the steel materials which contained C, Si, Mn, and Cr of the amount of specification of the above (a), and regulated the content of an impurity element / the processing front stirrup between the colds] machinability higher than the case where the grain boundary of the ferrite grain before cutting consists of only large inclination grain boundaries. In addition, the bearing difference of the crystal with which the "small angle tilt boundary" adjoined each other by saying the grain boundary whose bearing difference of the crystal with which the "large inclination grain boundary" as used in the field of this invention adjoined each other is 15 degrees or more says what includes the so-called "subgrain boundary" in the grain boundary which is less than 15 degrees.

[0016] (d) In order to raise the cold-working nature and machinability of steel materials of the above (a), the processing front stirrup between the colds should just rationalize the mean particle diameter of the cementite which is main carbide before cutting. Namely, if the mean particle diameter of a cementite is too small, since steel-materials reinforcement will rise, the deformation resistance in cold working will increase and the life of metal mold will fall at the time of processing. Furthermore, the cutting force in cutting increases and machinability also falls. On the other hand, if the mean particle diameter of a cementite is too large, since a cementite serves as a crack generating origin at the time of cold working, cold-working nature will fall, for example, the critical upsetting ratio in a compression test will fall. This invention is completed based on the above-mentioned knowledge.

[0017]

[Embodiment of the Invention] Hereafter, this invention is explained in detail. In addition, "% of the content" of a chemical entity means "mass %."

(A) C:0.8 - 1.1% of chemical composition C has the operation which rationalizes the amount of cementite survival under steel-materials organization after hardening annealing, and raises abrasion resistance. However, at less than 0.8%, the content is deficient in the addition effectiveness, and cannot secure desired abrasion resistance easily. On the other hand, since the above-mentioned big and rough carbide will remain even if it becomes easy to generate very big and rough carbide and performs homogenization heat treatment at the time of the coagulation of steel if the content of C exceeds 1.1%, a target rolling fatigue life is not acquired but cold-working nature also falls further. Therefore, the content of C was made into 0.8 - 1.1%. In addition, as for the content of C, considering as 0.9 - 1.0% is desirable.

[0018] Si: 0.1 - 1.5%Si has deacidification while raising a rolling fatigue life. In order to demonstrate such effectiveness, it is required to make 0.1% or more of Si contain. On the other hand, if the content of Si exceeds 1.5%, cold-working nature will deteriorate, for example, in case it is cold forging, it becomes easy to generate a crack. Therefore, the content of Si was made into 0.1 - 1.5%. In addition, as for the content of Si, considering as 0.2 - 0.8% is desirable.

[0019] Mn: 0.1 - 1.5%Mn has the operation which prevents the hot shortness by S while raising the hardenability of steel. In order to demonstrate such effectiveness, it is necessary to make Mn contain 0.1% or more. On the other hand, if the content of Mn exceeds 1.5%, cold-working nature will deteriorate, for example, in case it is cold forging, it becomes easy to generate a crack. Therefore, the content of Mn was made into 0.1 - 1.5%. In addition, as for the content of Mn, considering as 0.3 - 1.2% is desirable.
[0020] Cr: 0.2-2.0%Cr is an element which raises the hardenability of steel. Furthermore, since Cr condenses in a cementite and stabilizes a cementite in an austenite, the range can be made large whenever [for hardening / spheroidizing or stoving temperature], and manufacture of steel materials becomes easy. In order to demonstrate such effectiveness, it is necessary to make Cr contain 0.2% or more. However, since the above-mentioned big and rough carbide will remain even if it becomes easy to generate very big and rough carbide and performs homogenization heat treatment at the time of the coagulation of steel if the content of Cr exceeds 2.0%, a target rolling fatigue life is not acquired. Therefore, the content of Cr was made into 0.2 - 2.0%. In addition, as for the content of Cr, considering as 0.4 - 1.2% is desirable.
[0021] nickel: It is not necessary to add nickel 1.0% or less. If it adds, it has the operation which raises hardenability and raises a rolling fatigue life. In order to acquire this effectiveness certainly, as for the content of nickel, considering as 0.1% or more is desirable. However, if the content exceeds 1.0%, even if it hardens, the amount of the austenite (the so-called "retained austenite") which remains with un-metamorphosing will increase, and a rolling fatigue life will fall on the contrary. Therefore, the content of nickel was made into 1.0% or less. In addition, as for the upper limit of nickel content, considering as 0.8% is desirable.
[0022] Mo: It is not necessary to add Mo 1.0% or less. If it adds, it has the operation which raises hardenability and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, as for Mo, it is desirable to consider as 0.1% or more of content. However, if the content exceeds 1.0%, cold-working nature deteriorates, for example, in case it is cold forging, it will become easy to generate a crack. Therefore, the content of Mo was made into 1.0% or less. In addition, as for the upper limit of Mo content, considering as 0.6% is desirable.
[0023] Cu: It is not necessary to add less than [0.5%] Cu. If it adds, it has the operation which deposits minutely and raises a rolling fatigue life in steel. In order to acquire this effectiveness certainly, as for Cu, it is desirable to consider as 0.05% or more of content. However, if the content exceeds 0.5%, heat slowing nature may fall and a crack may occur in the case of processing between heat. Therefore, the content of Cu was made into 0.5% or less. In addition, as for the upper limit of Cu content, considering as 0.3% is desirable.
[0024] It is not necessary to add W:1.0%or less W. If it adds, it combines with C, detailed WC is formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, it is desirable to make the content of W into 0.05% or more. However, if the content exceeds 1.0%, since big and rough WC will be generated at the time of coagulation, a rolling fatigue life falls on the contrary. Therefore, the content of W was made into 1.0% or less. In addition, as for the upper limit of W content, considering as 0.3% is desirable.
[0025] Nb: It is not necessary to add less than [0.2%] Nb. If it adds, it combines with C, detailed NbC is formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to acquire this effectiveness certainly, as for Nb, it is desirable to consider as 0.03% or more of content. However, if the content exceeds 0.2%, since big and rough NbC will be generated at the time of coagulation, a rolling fatigue life falls on the contrary. Therefore, the content of Nb was made into 0.2% or less. In addition, as for the upper limit of Nb content, considering as 0.1% is desirable.
[0026] It is not necessary to add V:0.5%or less V. If it adds, it combines with C, detailed VC is

formed, and it has the operation which makes an austenite grain detailed and raises a rolling fatigue life. In order to demonstrate this effectiveness certainly, it is desirable to make the content of V into 0.05% or more. However, if the content exceeds 0.5%, since big and rough VC will be generated at the time of coagulation, a rolling fatigue life will fall on the contrary. Therefore, the content of V was made into 0.5% or less. In addition, as for the upper limit of V content, considering as 0.2% is desirable.

[0027] aluminum: It is not necessary to add aluminum 0.05% or less. It has deacidification, if it adds. In order to acquire this effectiveness certainly, as for aluminum, it is desirable to consider as 0.003% or more of content. However, if the content exceeds 0.05%, it will become easy to generate big and rough nonmetal system inclusion, and a target rolling fatigue life will not be acquired. Therefore, the content of aluminum was made into 0.05% or less. In addition, as for the upper limit of aluminum content, considering as 0.03% is desirable.

[0028] It is not necessary to add B:0.01%or less B. Abrasion resistance is raised, while dissolving in a cementite, stabilizing a cementite and enabling compaction of spheroidizing time amount, if it adds. In order to acquire such effectiveness certainly, as for B, it is desirable to consider as 0.0005% or more of content. However, if the content exceeds 0.01%, it will become easy to generate big and rough BN, and a target rolling fatigue life will not be acquired. Therefore, the content of B was made into 0.01% or less. In addition, as for the upper limit of B content, considering as 0.005% is desirable.

[0029] In this invention, the content of Ti, P, S, N, and O (oxygen) as an impurity element is restricted as follows.

[0030] Ti: 0.0030%or less Ti will combine with N, will form TiN, and will reduce a rolling fatigue life. If especially the content exceeds 0.0030%, the fall of a rolling fatigue life will become remarkable. Therefore, the content of Ti was made into 0.0030% or less.

[0031] Since it is easy to segregate P:0.02%or less P to a grain boundary, it will reduce a rolling fatigue life. When especially the content exceeds 0.02%, the fall of a rolling fatigue life is remarkable. Therefore, the content of P was made into 0.02% or less.

[0032] S:0.02%or less S combines with Mn, forms MnS, and may reduce a rolling fatigue life. If especially the content exceeds 0.02%, it will become easy to generate big and rough MnS, and the fall of a rolling fatigue life will become remarkable. Therefore, the content of S was made into 0.02% or less. However, since MnS is effective in improvement in machinability, it is desirable that S as an impurity element is included 0.005% or more from the field of machinability.

[0033] N:0.0090%or less N will combine with Ti or B, will form TiN and BN, and will reduce a rolling fatigue life. If especially the content exceeds 0.0090%, the fall of a rolling fatigue life will become remarkable. Therefore, the content of N was made into 0.0090% or less. In addition, in order to make a rolling fatigue life big, it is desirable to make the content of N into 0.0060% or less.

[0034] O (oxygen):0.0015%or less O will form oxide system inclusion, and will reduce a rolling fatigue life. When especially the content exceeds 0.0015%, the fall of a rolling fatigue life is remarkable. Therefore, the content of O was made into 0.0015% or less.

[0035] This invention does not need to add special limitation about other chemical entities other than the above in the target steel materials for bearing. Grant of the final product which consists of bearing element components and them, i.e., the property required of bearing, must be possible, and it must be the component range where the outstanding cold-working nature and machinability are obtained.

[0036] As an element except said, less than [Pb:0.30%], less than [rare-earth-elements:0.10%], less than [calcium:0.01%], and less than [Mg:0.01%] are contained, and, specifically, the remainder should just consist of Fe and an unescapable impurity.

[0037] In addition, when carrying out additional content of the above-mentioned element for the

purpose of the improvement in a property of the bearing which is steel materials, bearing element components, and a final product etc., it is desirable respectively to consider as a content (Pb:0.02-0.30%, rare-earth-elements:0.002-0.10%, calcium:0.0005-0.01%, and Mg:0.0005-0.01%).
(B) The workability which cold-working nature of steel materials of the chemical composition stated by the ferrite mean-particle-diameter above-mentioned (A) term improves that the processing front stirrup between the colds has the detailed ferrite grain which is a matrix before cutting, and a crack begins to generate, for example, the critical upsetting ratio in a compression test, goes up. Especially, when the mean particle diameter of a ferrite is 4.0 micrometers or less, improvement in cold-working nature becomes remarkable. On the other hand, from the point of raising cold-working nature, as ferrite mean particle diameter is small, it is better, but if the mean particle diameter of a ferrite is set to 1.0 micrometers or less, the increment in the deformation resistance between the colds will become remarkable, and the life of metal mold will fall remarkably at the time of processing. Therefore, the mean particle diameter of a ferrite was specified as 4.0 micrometers or less exceeding 1.0 micrometers. In addition, in order to control the fall of the mold life at the time of cold working, as for the mean particle diameter of a ferrite, it is desirable to make it 1.5 micrometers or more.
[0038] "Ferrite mean particle diameter" is defined as having already stated as follows. That is, it asks for the area of each ferrite grain first, asks for the diameter of circle which is an area equivalent to the area, and let it be the particle size of the appearance of each ferrite grain. Subsequently, the average of the particle size of the appearance of all the ferrite grains that measured area is made into apparent ferrite mean particle diameter, and what doubled the ferrite mean particle diameter of the above-mentioned appearance 1.12 is defined as ferrite mean particle diameter.
[0039] In addition, the direction in the case of including the small angle tilt boundary has machinability higher than the case where the grain boundary of the ferrite grain before cutting consists of only large inclination grain boundaries, and when especially the percentage of a small angle tilt boundary is 30% or more, machinability of the processing front stirrup between the colds improves. For this reason, as for the processing front stirrup between the colds, it is [the grain boundary of the ferrite grain before cutting] desirable for those 30% or more to be a small angle tilt boundary. As already stated, the grain boundary whose bearing difference of the crystal with which the "large inclination grain boundary" in this invention adjoined each other is 15 degrees or more is said, and a "small angle tilt boundary" points out that in which the bearing difference of the adjacent crystal includes the so-called "subgrain boundary" in the grain boundary which is less than 15 degrees.
(C) If the mean particle diameter of a cementite mean-particle-diameter cementite is too small, since steel-materials reinforcement will rise, the deformation resistance in cold working will increase and the mold life at the time of processing will fall. Furthermore, the cutting force in cutting increases and machinability also falls. Such a phenomenon becomes remarkable when the mean particle diameter of a cementite is less than 0.30 micrometers. On the other hand, if the mean particle diameter of a cementite is too large, since a cementite serves as a crack generating origin at the time of cold working, cold-working nature will fall, for example, the critical upsetting ratio in a compression test will fall. This phenomenon will become remarkable if the mean particle diameter of a cementite exceeds 0.80 micrometers. Therefore, cementite mean particle diameter was specified as 0.30-0.80 micrometers. "Cementite mean particle diameter" is defined as having already stated as follows. That is, it asks for the area of each cementite grain first, asks for the diameter of circle of an area equivalent to the area, and let it be the particle size of the appearance of each cementite grain. Subsequently, the average of the particle size of the appearance of all the cementite grains that measured area is made into apparent cementite mean particle diameter, and what doubled the cementite mean particle

diameter of the above-mentioned appearance 1.12 is defined as cementite mean particle diameter.

[0040] The steel materials for bearing which have the chemical composition indicated in the aforementioned (A) term For example, the round bar with a diameter of 30mm hot-rolled and obtained by the usual approach (A1 Point +15) - (A1 point +40), after heating in the temperature region of ** for 2 to 4 hours After cooling to the temperature of ** at least (A1 point -80) with the cooling rate of 10-15 degrees C/o'clock, it cools radiationally among atmospheric air. After carrying out cold drawing at 20 - 40% of reduction of area further after that - (A1 point -20) (A1 point -60), ferrite mean particle diameter and cementite mean particle diameter can be adjusted to the value stated by the (B) term and the (C) term by heating by ** for 0.5 to 2 hours. Subsequently, the steel materials are rough-fabricated by the desired configuration by cold forging or cutting, and after receiving hardening and annealing after that, machining grinding, polish, etc. further and making a desired precise element part shape, they are assembled by the bearing as a final product which is a precision machinery component.

[0041] In addition, what combined the cold drawing of the spheroidizing conditions of "I" in the below-mentioned example and 32% of reduction of area and the heat treatment conditions of "Y" agrees on the adjustment conditions of the above-mentioned ferrite mean particle diameter and cementite mean particle diameter.

[0042] In addition, said A1 A point points out the value calculated from the following formula considering the symbol of element in a formula as a content in mass % of the element.

[0043] A1 Point =723-10.7Mn-16.9nickel+29.1Si+16.9Cr+6.4 (W+Mo).

[Translation done.]

EXAMPLE

[Example] Steel A-J which has the chemical composition shown in Table 1 was ingoted using 300kg vacuum furnace by the usual approach. In addition, the chemical composition of the steel A in Table 1 is equivalent to SUJ2 of JIS.
[0045]
[Table 1]

表 1

鋼	化学組成（質量%） 残部：Feおよび不純物																
	C	Si	Mn	Cr	Ni	Mo	Cu	W	Nb	V	Al	B	Ti	S	P	N	O
A	1.00	0.25	0.32	1.41	-	-	-	-	-	-	0.021	-	0.0012	0.008	0.005	0.0048	0.0008
B	*0.74	0.23	0.33	1.43	-	-	-	-	-	-	0.023	-	0.0011	0.007	0.006	0.0045	0.0007
C	0.84	0.24	0.34	1.42	-	-	-	-	-	-	0.020	0.0048	0.0012	0.008	0.006	0.0046	0.0008
D	*1.14	0.23	0.35	1.40	-	-	-	-	-	-	0.018	-	0.0010	0.009	0.005	0.0043	0.0007
E	0.89	0.52	0.80	0.75	0.51	-	0.24	-	-	-	0.028	-	0.0021	0.008	0.007	0.0045	0.0010
F	0.94	0.40	1.05	0.41	-	0.20	-	0.23	-	-	0.026	-	0.0012	0.006	0.005	0.0058	0.0009
G	0.85	0.45	0.52	1.02	-	-	-	-	0.012	0.022	0.001	-	0.0008	0.007	0.004	0.0041	0.0011
H	0.90	0.25	0.72	0.84	-	-	-	-	-	-	0.023	-	*0.0033	0.008	0.006	0.0047	0.0006
I	0.91	0.24	0.71	0.83	-	-	-	-	-	-	0.024	-	0.0012	0.006	0.006	*0.0095	0.0008
J	0.90	0.24	0.74	0.81	-	-	-	-	-	-	0.021	-	0.0009	0.008	0.005	0.0043	*0.0017

*印は本発明で規定する範囲から外れていることを表す 。
Ni,Mo,Cu,Wの欄の「-」は0.01%未満、Nb,Vの欄の「-」は0.001%未満、Bの欄の「-」は0.0001%未満を表す。

Subsequently, after carrying out soaking of the steel materials of such steel at 1230 degrees C for 8 hours, hot forging was carried out by the usual approach in the 1150-950-degree C temperature region, and it considered as the round bar whose diameter is 50mm.
[0046] Then, spheroidizing was performed on condition that following I, RO, or Ha.
[0047] I: Cool to 660 degrees C in o'clock in 60 degrees C /, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 1 hour.
[0048] RO: Cool to 660 degrees C in o'clock in 10 degrees C /, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 4 hours.
[0049] Ha: Cool to 660 degrees C in o'clock in 5 degrees C /after cooling to 680 degrees C in o'clock in 5 degrees C /and reheating at 770 degrees C after that for 6 hours, and cool radiationally among atmospheric air after that, after heating at 770 degrees C for 6 hours.
[0050] Thus, after carrying out the grinding process of the front face of the obtained round bar and making it the round bar with a diameter of 45mm, cold drawing was carried out by the usual approach, and it was processed into the round bar (the diameter of 42mm (the reduction of area from the diameter of 45mm: 13%), 37mm (the reduction of area from the diameter of 45mm: 32%), and 29mm (the reduction of area from the diameter of 45mm: 58%)). Subsequently, it heat-treated on condition that either Following X, or Y and Z about the round bar which carried out [above-mentioned] cold drawing, respectively.

[0051] Radiationnal cooling among atmospheric air after heating at X:600 degrees C for 1 hour.
[0052] Radiationnal cooling among atmospheric air after heating at Y:700 degrees C for 1 hour.
[0053] Radiationnal cooling among atmospheric air after heating at Z:700 degrees C for 8 hours.
[0054] After carrying out cold drawing to 42-29mm for the round bar which carried out the grinding process to 45mm after spheroidizing, and a diameter, ferrite mean particle diameter and cementite mean particle diameter were measured about the round bar which heat-treated on condition that either of said X-Z.
[0055] That is, after carrying out mirror polishing of the cross section (that is, cutting plane right-angled in the die-length direction) of each round bar, it corroded in picral. Subsequently, it observed five visual fields each by one 5000 times the scale factor of this using the scanning electron microscope, and by the image analysis by the usual approach, it asked for the area of each ferrite grain and each cementite grain, and the diameter of circle of an area equivalent to it was calculated, and the average of a diameter of circle was respectively calculated about the ferrite grain and the cementite grain. What doubled the average of this diameter of circle 1.12, respectively was made into ferrite mean particle diameter and cementite mean particle diameter. Moreover, about the round bar which uses steel A as material steel, mirror polishing and after carrying out electrolytic polishing, bearing of a ferrite grain was measured for the cross section of each round bar by the electron ray backscattering pattern method (EBSP), and it asked for the rate of a small angle tilt boundary.
[0056] The cold-working trial was performed as follows. That is, after cutting down the test piece with a die length of 21mm for the diameter of 14mm from the round bar produced with said monograph affair, compressing the test piece, where the both-ends side of a test piece is restrained, and compressing 15% of the original test piece die length (21mm) in the 0.5/second of rate of strains, it repeated carrying out unloading 4 times. Then, after the original test piece die length's having compressed by a unit of 2% further and carrying out unloading, the test piece was observed with the naked eye, and the existence of a crack was checked. It continued until the crack generated this in the test piece. In addition, the above-mentioned trial was performed using ten test pieces each, and workability which a crack began to generate in five or more test pieces among ten test pieces was made into marginal workability. In addition, it asked for marginal workability from the following formula.
[0057] Marginal workability (%) =100 (21-h) / 21. Here, h points out the height in mm unit of the test piece which a crack began to generate to five or more test pieces.
[0058] The target of cold-working nature (compressibility between the colds) was carried out compared with the marginal workability (70%) in the test number 3 using the steel A equivalent to SUJ2 of JIS to the thing high 5% or more, i.e., have 75% or more of marginal workability.
[0059] The cutting trial was also performed. That is, acid washing of the round bar produced with said monograph affair was carried out by the usual approach, the cutting process by turning was performed using what removed the scale, time amount until it becomes impossible for a tool to cut by wear or the chip was measured, and the tool life was searched for. The cutting process by turning was performed on condition that a part for /and the amount of slitting of 0.5mm of peripheral speed of 50m, and feed-per-revolution 0.25 mm/rev., and used the triangular chip of SKH4 of JIS for the tool. In addition, lubricant was not used.
[0060] It was presupposed to the target of machinability that it has a ********, i.e., the tool life for 6.0 minutes or more, 50% or more compared with the tool life (4.0 minutes) in the test number 3 using the steel A equivalent to SUJ2 of JIS.
[0061] The test piece with a die length of 22mm was cut down for the diameter of 12mm from the round bar produced with said monograph affair, annealing of 1 hour was given at oil-

quenching of maintenance, and 160 degrees C by 820 degrees C for 30 minutes, and the rolling fatigue test was performed.
[0062] That is, using the cylindrical rolling fatigue tester, #60 spindle oil was used for the lubricating oil, and Hertz best osculation stress performed the rolling fatigue test on the load conditions of 4900MPa(s) (500kgf/mm2) and rotational-speed 46000rpm. It made the test piece into ten pieces at a time about said monograph affair, and the total rotational frequency when causing surface exfoliation first in ten test pieces was made into the "rolling fatigue life." In addition, the target of a rolling fatigue life is 1x107. It considered as the above.
[0063] Furthermore, the test piece with a die length of 10mm was cut down for the diameter of 28mm from the round bar produced with said monograph affair, annealing of 1 hour was given at oil-quenching of maintenance, and 160 degrees C by 820 degrees C for 30 minutes, and the abrasion test was performed. That is, using an Ogoe style abrasion tester, SCM420 which adjusted hardness to 87 by HRB was made into partner material, and was performed on condition that the friction velocity of 1m/second, the friction distance of 400m, 59 Ns (6kgf) of breaking loads, and non-lubrication. It made the test piece into five pieces at a time about each steel, and the average of the abrasion loss of five test pieces was made into abrasion loss. In addition, the wear-resistant target was made into 1.0 or less abrasion loss at the time of setting abrasion loss in the test number 3 using the steel A equivalent to SUJ2 of JIS to 1.0.
[0064] The conditions of spheroidizing, the reduction of area at the time of wire drawing, ferrite mean particle diameter, cementite mean particle diameter, the marginal workability [in / comparatively / the compression test between the colds] of the small angle tilt boundary in a ferrite grain boundary, the tool life in a cutting trial, the rolling fatigue life in a rolling fatigue test, and the abrasion loss in an abrasion test are collectively shown in Table 2 and Table 3.
[0065]
[Table 2]

表 2

試験番号	鋼	球状化焼鈍の条件	冷間伸線減面率(%)	冷間伸線後の熱処理	フェライト平均粒径(μm)	セメンタイト平均粒径(μm)	小傾角粒界の割合(%)	限界加工度(%)	工具寿命(分)	転動疲労寿命(回)	摩耗量
1		イ	0	なし	*12.8	*0.24	12	** 68	**1.5	3.8×10^7	1.0
2		イ	32	Y	* 0.8	*0.27	49	76	**4.5	3.9×10^7	1.0
3		ロ	0	なし	*14.3	0.48	10	** 70	**4.0	4.3×10^7	1.0
4		ロ	13	Y	*13.4	0.50	15	** 68	**4.5	4.3×10^7	1.0
5	A	ロ	32	X	* 8.6	0.49	31	** 70	**3.0	4.3×10^7	1.0
6		ロ	32	Y	1.2	0.51	63	82	9.5	4.5×10^7	1.0
7		ロ	32	Z	1.8	0.58	37	78	10.0	4.2×10^7	1.0
8		ロ	58	Y	1.1	0.51	50	80	11.5	4.3×10^7	1.0
9		ハ	0	なし	*20.1	*0.83	6	** 68	6.0	4.0×10^7	1.0
10		ハ	32	Y	1.7	*0.85	44	** 70	14.5	4.2×10^7	1.0
11		ロ	32	X	* 6.5	0.42	—	** 72	6.5	2.5×10^7	**1.6
12	*B	ロ	32	Y	1.6	0.43	—	84	12.0	2.7×10^7	**1.6
13		ロ	32	Z	* 2.9	0.47	—	80	8.5	3.0×10^7	**1.6
14		ロ	0	なし	*15.2	0.44	—	** 72	**5.5	3.9×10^7	0.9
15		ロ	13	Y	* 7.7	0.45	—	** 70	**4.5	4.3×10^7	0.9
16	C	ロ	32	X	*14.5	0.44	—	** 68	**3.5	4.3×10^7	0.9
17		ロ	32	Y	1.5	0.46	—	80	13.0	4.3×10^7	0.9
18		ロ	32	Z	* 4.3	0.50	—	** 74	7.0	4.5×10^7	0.9
19		ロ	58	Y	1.2	0.46	—	82	13.5	4.2×10^7	0.9
20		ロ	32	X	* 9.4	0.62	—	** 66	**1.5	**6.3×10^6	0.7
21	*D	ロ	32	Y	* 4.8	0.63	—	** 68	**1.0	**5.8×10^6	0.7
22		ロ	32	Z	1.6	0.66	—	76	7.0	**6.0×10^6	0.7
23		ロ	0	なし	*12.0	0.45	—	** 72	**5.5	6.2×10^7	1.0
24	E	ロ	13	Y	*10.8	0.47	—	** 70	**4.5	6.4×10^7	1.0
25		ロ	32	X	*11.5	0.46	—	** 70	7.0	6.3×10^7	1.0

*印は、本発明で規定する条件から外れていることを示す。
**印は、目標に達していないことを示す。
小傾角粒界の割合における「—」は測定していないことを示す。
摩耗量は試験番号３の摩耗量を１．０とした場合の相対的な値を示す。

[Table 3]

表 3

試験番号	鋼	球状化焼鈍の条件	冷間伸線減面率(%)	冷間伸線後の熱処理	フェライト平均粒径(μm)	セメンタイト平均粒径(μm)	小傾角粒界の割合(%)	限界加工度(%)	工具寿命(分)	転動疲労寿命(回)	摩耗量
26		ロ	32	Y	1.6	0.47	—	82	12.0	6.8×10⁷	1．0
27		ロ	32	Z	2.8	0.51	—	76	9.5	5.9×10⁷	1．0
28		ロ	58	Y	1.5	0.47	—	84	13.0	6.3×10⁷	1．0
29		ロ	0	なし	* 9.7	0.51	—	** 68	**7.6	7.3×10⁷	0．5
30	F	ロ	13	Y	* 9.3	0.52	—	** 70	**3.5	6.9×10⁷	0．5
31		ロ	32	X	* 9.6	0.51	—	** 66	**4.0	7.0×10⁷	0．5
32		ロ	32	Y	* 5.1	0.52	—	** 72	**5.5	7.2×10⁷	0．5
33		ロ	32	Z	1.6	0.55	—	78	8.0	6.5×10⁷	0．5
34		ロ	58	Y	1.2	0.52	—	80	9.5	7.1×10⁷	0．5
35		ロ	0	なし	* 7.9	0.45	—	** 64	**2.0	8.2×10⁷	0．7
36		ロ	13	Y	* 7.2	0.46	—	** 66	**1.5	7.5×10⁷	0．7
37	G	ロ	32	X	* 7.0	0.45	—	** 68	**3.0	7.7×10⁷	0．7
38		ロ	32	Y	3.4	0.46	—	76	6.5	8.0×10⁷	0．7
39		ロ	32	Z	1.3	0.50	—	76	8.5	7.9×10⁷	0．7
40		ロ	58	Y	1.2	0.47	—	78	9.0	7.3×10⁷	0．7
41		ロ	32	X	*13.5	0.48	—	** 70	**5.5	**5.2×10⁶	0．9
42	*H	ロ	32	Y	1.6	0.49	—	78	11.0	**5.8×10⁶	0．9
43		ロ	32	Z	* 3.1	0.54	—	** 74	8.5	**5.6×10⁶	0．9
44		ロ	32	X	*12.9	0.48	—	** 70	**4.5	**8.0×10⁶	0．9
45	*I	ロ	32	Y	1.5	0.50	—	80	9.0	**8.3×10⁶	0．9
46		ロ	32	Z	* 4.3	0.55	—	** 74	6.5	**7.6×10⁶	0．9
47		ロ	32	X	*13.2	0.49	—	** 68	**5.0	**2.7×10⁶	0．9
48	*J	ロ	32	Y	1.5	0.50	—	78	12.5	**3.0×10⁶	0．9
49		ロ	32	Z	3.3	0.56	—	76	9.0	**2.3×10⁶	0．9

*印は、本発明で規定する条件から外れていることを示す。
**印は、目標に達していないことを示す。
小傾角粒界の割合における「－」は測定していないことを示す。
摩耗量は試験番号3の摩耗量を1．0とした場合の相対的な値を示す。

In the case of the test numbers 6-8 which fill the provision of this invention from Table 2 and Table 3, 17, 19, 26-28, 33 and 34, and 38-40, it is 75% or more of marginal workability, a tool life for 6.0 minutes or more, and 1x107. The above rolling fatigue life is acquired and the abrasion resistance on the basis of the abrasion loss of a test number 3 is also good. On the other hand, even if there are little marginal workability, tool life, rolling fatigue life, and abrasion resistance in the case of the test number from which it separated from the provision of this invention, either has not reached a target.
[0066] Even if it is the case where Steel A and C and E-G which have chemical composition within the limits of the content specified by this invention are used as material steel, since [of ferrite mean particle diameter and cementite mean particle diameter] either separates from the provision of this invention at least, as for test numbers 1-5, 9, 10, 14-16, 18, 23-25, 29-32, and 35-37, marginal workability, one of tool lives, or both sides has not reached a target.
[0067] Namely, since cementite mean particle diameter is less than 0.30 micrometers while ferrite mean particle diameter exceeds 4.0 micrometers, a test number 1 has marginal workability as small as 68%, and its tool life is also as short as 1.5 minutes.
[0068] Since cementite mean particle diameter is less than 0.30 micrometers, a test number 2 has a tool life as short as 4.5 minutes.
[0069] In order that ferrite mean particle diameter may exceed 4.0 micrometers, test numbers 3-5, 23, 24, 29-32, and 35-37 have low marginal workability, and its a tool life is also short.

[0070] A test number 9 has marginal workability as small as 68%, in order that ferrite mean particle diameter may exceed [4.0 micrometers] 0.80 micrometers also for cementite mean particle diameter with an upper time.
[0071] In order that, as for a test number 10, cementite mean particle diameter may exceed 0.80 micrometers, marginal workability has not reached desired value at 70%. In order that ferrite mean particle diameter may exceed 4.0 micrometers, test numbers 14-16, and 18 and 25 have low marginal workability. On the other hand, since C content of the steel B which is material steel is less than 0.8%, there is much abrasion loss and test numbers 11-13 are inferior in abrasion resistance. Among these, as for the test number 11, marginal workability has not reached desired value, either.
[0072] Test numbers 20-22 have a short rolling fatigue life, in order that C content of the steel D which is material steel may exceed 1.1%. Among these, as for test numbers 20 and 21, marginal workability has not reached desired value, either.
[0073] In order that the content of Ti, N, and O (oxygen) of steel H-J which is material steel may exceed 0.0030%, 0.0090%, and 0.0015%, respectively, test numbers 41-43, 44-46, and 47-49 have a short rolling fatigue life. Among these, as for test numbers 41, 43, 44, 46, and 47, marginal workability has not reached desired value, either. Furthermore, in the case of test numbers 41, 44, and 47, a tool life is also short.

[Translation done.]